APOLLO
OPTICAL SUBSYSTEM
AND
LM ALIGNMENT OPTICAL TELESCOPE

FINAL REPORT

VOLUME I - PROGRAM SUMMARY

February 1970

Prepared For
AC Electronics Division
General Motors Corporation
Milwaukee, Wisconsin

Kollsman Instrument Corporation
Syosset, New York

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APOLLO
OPTICAL SUBSYSTEM
AND
LM ALIGNMENT OPTICAL TELESCOPE

PROGRAM SUMMARY

VOLUME I

Subcontract No. FNP 12776
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Program Director

KOLLSMAN INSTRUMENT CORPORATION
Syosset, New York

FOREWORD

This document constitutes the Final Report of the Apollo Optical Subsystem and the LM Alignment Optical Telescope program. The report is prepared in conformance with the requirements as specified in the NASA ACED Contract NAS 9-497 and is presented in two volumes.

Volume I	-	Program Summary	
Volume II	-	Final Report (two books)	
Part 1		Section 1	Introduction
		Section 2	Program Management
		Section 3	Technical Approach
		Section 4	Engineering
Part 2		Section 5	Reliability
		Section 6	Quality Assurance
		Section 7	Documentation
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KOLLSMAN INSTRUMENT CORPORATION

INTRODUCTION

History will record the events that occurred during the planning, development, and implementation of the Apollo Program. It will discuss the factors that led to the development, the temper of the nation during the performance and the impact that the total program has had on the nation and the world as a whole. This report will form part of that history.

History has a very practical aspect--that being, the knowledge gained by a review of the past assists us in setting a course for the future. To a degree the mistakes of the past can help in avoiding the pitfalls that may loom in the future but, more significantly, each success of the past should serve as a stepping stone for the betterment of all mankind. The Apollo program, because of the massiveness of its undertaking and the indisputable nature of its success must be seriously considered toward that purpose.

It has been speculated that the undertaking of this program has been the greatest undertaking in all the history of mankind, exceeding the mobilization of defense and industry at the beginning of World War II. This undertaking which we can now describe as a series of established facts was so large, so all encompassing in nature, so demanding in its requirements and so idealistic in its aspirations that our national language is hard pressed to supply words which can adequately describe it. Yet, if we are to profit by what we have done we must have a full understanding of the essence of the action.

In compliance with the Statement of Work of the Apollo contract the Kollsman Instrument Corporation herewith submits its final report. In addition to providing the significant milestones, series of events and associated statistics, it is our earnest desire that this report will also supply the greatest possible degree of insight into what has made this a successful program. It is our feeling that if we can properly project how Kollsman has managed this program then by multiplying by a thousand fold perhaps we might provide a broader insight into how the total program has become a success.

It is appropriate to note, at this time, that as outstanding as the engineering accomplishments have been, we will not find here the real essence for success. Rather we will find a tool for success. We suspect that, on deeper reflection, we will find that the development of people, of attitudes and motives, in short, a major innovation in people's thinking and how this was accomplished is the "key" to the success of Apollo.

KOLLSMAN INSTRUMENT CORPORATION

SCOPE OF EFFORT

Kollsman's performance on the Apollo Program covers the period May 1962 through December 1969. As prime contractor to NASA, Kollsman's basic responsibility was to develop, fabricate, test and support flight hardware and associated Ground Support Equipment (GSE) for the Apollo Guidance and Navigation (G&N) System. In addition, Kollsman assisted the Massachusetts Institute of Technology Instrumentation Laboratory (MIT/IL) during the design phase of this hardware with a team of resident senior engineers, designers, and draftsmen. The design responsibility for the hardware was that of MIT/IL who was also prime to NASA.

In July of 1964 AC Electronics assumed prime responsibility for all G&N equipment. From this point through the balance of the program, Kollsman performed as a subcontractor to AC Electronics. MIT/IL continued as the design cognizant agency.

All changes to the Statement of Work (SOW), during the early phases of the program, were dictated by MIT/IL with contractual changes authorized directly by NASA. During AC Electronics tenure as prime contractor, all contractual changes were directed and authorized by AC Electronics.

In addition to the fabrication of prime and GSE hardware, Kollsman implemented a dynamic Quality Assurance program. The reliability portion of this program is delineated in the Command and Lunar Excursion Module's Reliability Plan and includes studies, tests, analyses and reports on such items as: materials, design verification tests, qualification testing of prime hardware, qualification testing of components, extended performance testing (E.P.T.) of vendor supplied parts, program reviews and controls, training, reliability studies, design reviews and manufacturing support.

The quality control portion of this program includes such controls as: supplier evaluation and surveillance, quality fabrication and test, documentation, systems and procedures. It includes the generation and issuance of Q.C. manuals, handbooks, specifications and procedures, performance of audits, administration of MRB, performance of effective design review and so on. Perhaps one of the most formidable tasks which was performed by QC was the successful negotiation with suppliers of ND 1015404 (General Spec. Configuration, Process and Quality Control Requirements for Suppliers of High Reliability Articles for use in Apollo G&N Systems). Considering the low volume of parts requirements, the development and persuasion of vendors toward meeting the full letter and spirit of this far reaching specification is unprecedented in the annals of Q.C. controls.

Kollsman, additionally, developed and trained a strong Field Operations group to perform complete maintainability and field operations functions including the manning of field sites at:

AC Electronics, Milwaukee, Wisconsin

NASA Manned Spacecraft Center (MSC), Houston, Texas

North American Rockwell (NAR), Downey, California

Kennedy Space Center (KSC), Cape Kennedy, Florida

Grumman Aircraft Engineering Corp., Bethpage, New York

The implementation of a heavy documentation, control and reporting system was a foremost and challenging requirement. In October 1964, the documentation burden was further increased with the introduction of the new and more stringent regulation NPC 500-1 (Apollo Configuration Management Manual).

As the program progressed, numerous non-interchangeable design changes resulted in the recycling of units back to Kollsman for retrofit purposes. In some instances, retrofits were successfully implemented at field sites.

For the period July 1, 1968 thru December 31, 1969, a repair program was integrated with the total contractual commitment.

The above stated scope of effort is delineated, in detail, in Volume II of this report which, in turn, is a condensation of the thousands of documents that were prepared during the course of the program. These documents describe items of hardware and software and, all of the events and activity which took place.

KOLLSMAN INSTRUMENT CORPORATION

HARDWARE DESCRIPTION

A brief functional description of the hardware for which Kollsman had designated responsibility is as follows:

1. OPTICAL UNIT ASSEMBLY (OUA)

The OUA consists of two optical instruments; a sextant (SXT), and a scanning telescope (SCT), mounted on a common base and used in the Apollo Command Module (CM). The SCT is a low power instrument with a wide field of view and is used for general celestial viewing and recognition of target bodies. It is also used for initial orientation of the Inertial Measurement Unit (IMU). In addition, it is used to track landmark points during earth and lunar orbits. The SXT is a highly accurate high power magnification instrument with a narrow field of view. It is capable of sighting two celestial targets simultaneously and measuring the angle between them. The SXT is used for IMU orientation and reorientation by sighting on two celestial bodies. In addition, it is used for celestial navigation by using star-horizon or star-landmark measurements. It is capable of tracking landmark points during earth and lunar orbits.

2. ALIGNMENT OPTICAL TELESCOPE (AOT)

The AOT is a periscopic telescope with a wide field of view and is manually rotated to each of six detent positions. It is used in the Apollo Lunar Module (LM). The AOT function is to provide IMU orientation or alignment in lunar orbit and on the lunar surface by sighting on two celestial bodies.

3. MAP AND DATA VIEWER (MDV)

The MDV along with the OUA comprise the original optical subsystem for use in the Command Module G&N system. The MDV was mounted in the top portion of the Lower Display Control Panel of the CM. The purpose of the MDV was to provide the astronauts with inflight visual display of pertinent flight data and at the same time indicate condition of critical G&N system circuits through annunciators (warning lights). Information such as navigational charts, computer settings, flight instructions, etc. were to be contained on 50 foot spools of 16mm film and stored in mechanized cartridges. Each cartridge held sufficient film to catalog 2000 separate frames of data. Subsequent to Block I, NASA decided to delete this item of hardware.

4. APOLLO RANGEFINDER

Downstream in the program Kollsman was requested to develop and fabricate a Rangefinder to aid in the rendezvous operation between the CM and the LM. The Rangefinder is an optical ranging device employing the diastimeter principle. With known LM target size the distance of the LM from the CM can be readily indicated by viewing the subtended angle of the target vehicle. The instrument automatically interpolates for direct read-out of nautical miles.

5. GROUND SUPPORT EQUIPMENT (GSE) AND FACTORY TEST EQUIPMENT (FTE)

Kollsman developed and fabricated test equipment suitable to build, test and field support the above listed flight hardware.

In the course of OUA development the units were released in blocks, known as Block I, Block I-50, Block I-100, and Block II. Behind each designation change was a definite purpose designed expressly to enhance the performance of the Guidance and Navigation System.

The Block I-50 systems were basically a redefinition of Block I OUA's with nominal configuration changes. The Block II configuration contained the following major changes:

a. Incorporation of New Motor Tachometers - provided additional power for an increased mechanical load.

b. Application of High Efficiency Optical Coatings - improve transmissability.

c. Quick Disconnect Eyepieces with Heater Feature - provided astronaut with a quick change capability and an anti-fogging feature.

d. Large Diameter Optical Base - change implemented to accommodate an interface requirement.

e. Inclusion of Electronics (tracker/photometer) - Provided astronauts with an automatic star tracking and horizon measurement capability.

During the early phases of the Block II development NASA determined that considerable cost savings could be effected by deleting the Tracker/Photometer requirement. A number of OUA's embodying the main feature of the Block II OUA configuration were redesignated Block I-100. These units contained Tracker/Photometer electronics in various stages. The Tracker/Photometer was deleted from the Block II OUA's.

The first flyable (unmanned) OUA's were selected from the Block I-50 group. This group was comprised of the last four OUA's from the original Block I design. The manned flyable OUA's were from the Block II units.

During the course of the program the following units were delivered:

Block I OUA's - 13 units during the period 7/64 to 4/65.

Block I-100 OUA's - 8 units during the period 5/65 to 2/66.

Block II OUA's - 22 units during the period 4/66 to 1/69.

In the course of AOT development, numerous changes were made to enhance it's performance. The most significant of these were:

a. Moisture Proofing of Counter envelope - to prevent moisture accumulation during humidity condition, and to prevent fogging of the window.

b. Metallic Flame Protector - fireproof AOT seal.

c. Added heater capability to AOT eyepieces to prevent fogging of eyepiece optics.

d. Sun Shade - eliminate stray light, and permit the addition of three usable detent positions..

The following AOT's were delivered:

Breadboard - 4 units

Preproduction - 7 units

Production - 19 units

Sun protect (high density) filters were designed, developed, and fabricated for use with the AOT eyepiece.

Eyepieces - The Block I OUA configuration included eyepieces as an integral part of the OUA. Each eyepiece set was optically matched to an OUA and was delivered on a one-for-one basis. The Block II eyepieces were delivered as separate Contract End Items and were redesigned to be optically interchangeable with all OUA's. In addition the Block II eyepieces incorporated the following features: quick disconnect, anti-fogging, circuit protect.

Sun protect (high density) filters were designed, developed and fabricated for use with SCT and SXT eyepieces.

The MDV was developed under the design cognizance of MIT. A total of 12 units were fabricated and delivered.

The Apollo Rangefinder was designed, developed and fabricated by Kollsman performing as a subcontractor to AC Electronics. A total of four rangefinders were delivered.

A schedule of all hardware deliveries and retrofits, performed under this contract, is shown in Tables 1 through 3.

Table 1. Apollo CM Deliveries

BLOCK I

OPTICAL UNIT ASSY

UNIT	DEL DATE
AGE 5A	JUL-64
1	MAR-64
2	APR-64
3	FEB-64
4	MAY-64
5	JUN-64
6	JUL-64
7	AUG-64
8	OCT-64
20	DEC-64
17	JAN-65
12	MAR-65
SPARE	APR-65

MAP & DATA VIEWER

	DEL DATE
AGE 5A	JUL-64
1	FEB-64
2	MAR-64
4	MAR-64
5	APR-64
6	JUN-64
7	DEC-64
8	DEC-64
20	JAN-65
17	FEB-65
12	MAR-65
MAA SIMULATOR	FEB-65

RANGEFINDER

UNITS	DEL DATE
1 (Qual.)	1-24-69
1	1-30-69
1	2-7-69

BLOCK I-100

OPTICAL UNIT ASSY

UNIT	DEL DATE
LM	5-13-65
G & N EL BB 1	5-24-65
AGE 102	7-5-65
121	8-10-65
EL BB 2	6-15-65
EL BB 3	7-16-65
110	9-28-65
111	9-24-65
101	8-24-65
122	11-10-65
109	11-29-65
123	12-17-65

EYEPIECES

	DEL DATE
2 SETS	6-15-66
2 SETS	6-30-66
1 SET	7-15-66
1 SET	7-19-66
2 SETS	7-29-66
2 SETS	8-19-66
3 SETS	8-26-66
2 SETS	9-2-66
2 SETS	9-7-66
2 SETS	9-15-66
1 SET	11-17-66
3 SETS	12-7-66
2 SET	12-30-66
1 SCT LER	6-15-66
2 SCT LER	6-30-66
2 SCT LER	9-15-66
2 SXT LER	9-15-66
2 SCT LER	9-22-66
2 SXT LER	9-22-66
2 SCT LER	9-29-66
2 SXT LER	9-29-66
1 SCT LER	10-25-68
1 SXT LER	10-25-68
1 SCT LER	11-25-68
1 SXT LER	11-25-68

BLOCK II

OPTICAL UNIT ASSY

	DEL DATE
AGE 124 (201A	2-5-66
200	4-29-66
201	2-19-66
202	4-24-66
203	5-27-66
204	6-8-66
205	7-29-66
206	9-8-66
207	3-7-67
208	11-7-66
209	1-27-67
210	3-14-67
211	3-27-67
212	4-18-67
213	6-7-67
214	7-25-67
215	9-22-67
216	11-2-67
217	1-25-68
218	3-29-68
219	6-6-68
220	12-13-68
221	9-30-68
MECH GAGE	11-29-65
SPARE I-201	5-12-66

EYEPIECE FILTERS

(SCT & SXT)

	DEL DATE
1 SET	11-21-68
2 SETS	12-2-68
1 SET	2-28-69
1 SET	3-3-69
1 SET	3-14-69
1 SET	3-20-69
1 SET	4-10-69
1 SET	4-24-69
1 SET	5-16-69
2 (SCT ONLY)	5-26-69
2 " "	6-16-69
2 " "	6-25-69
1 " "	6-27-69

EYEPIECE KITS

(TEFLON RINGS)

	DEL DATE
1 KIT	6-12-69
2 KITS	6-25-69
1 KIT	1-27-69
12 KITS	7-3-69

EYEPIECE (SCT LER) KITS

(CLAMPING RING)

	DEL DATE
1 KIT	11-21-68
2 KITS	11-25-68
7 KITS	12-20-68

EYEPIECE COVERS RETROFITS

	DEL DATE
2 SETS	6-21-68
3 SETS	7-9-68
7 SETS	7-24-68
1 SET	7-26-68
4 SETS	9-5-68
5 SETS	9-25-68
7 SETS	12-31-68
1 SET	1-20-69
2 SETS	10-27-69

EYEPIECE KITS

(STEEL INSERTS)

	DEL DATE
2 KITS	11-15-68
4 KITS	11-20-68
6 KITS	1-27-69
5 KITS	3-7-69
1 KIT	4-30-69
1 KIT	5-9-69

BLOCK II

EYEPIECE SETS RETROFITS

	DEL DATE
1 EYEPIECE SET (+ 1 SCT LER)	2-20-68
2 EYEPIECE SETS (+ 2 SCT LER'S)	3-15-68
1 EYEPIECE SET	3-29-68
1 EYEPIECE SET	4-12-68
2 EYEPIECE SETS	4-30-68
1 EYEPIECE SET (+ 1 SCT LER)	5-13-68
1 EYEPIECE SET	6-3-68
2 EYEPIECE SETS (+ 2 SCT LER's)	6-18-68
2 EYEPIECE SETS (+ 2 SCT LER's)	7-3-68
2 EYEPIECE SETS	7-17-68
1 EYEPIECE SET	7-26-68
1 EYEPIECE SET	8-28-68
1 EYEPIECE SET	8-30-68
1 EYEPIECE SET	9-17-68
1 EYEPIECE SET	9-30-68

OUA RETROFITS

	DEL DATE
AGE 201A	9-2-66
201A	10-19-67
1-201	8-19-66
1-201	9-25-68
208	12-21-67
206	3-13-68
202	8-26-66
202	5-1-68
209	5-24-68
209	6-11-68
203	7-29-66
203	6-27-68
204	7-29-66
204	7-26-68
205	9-14-68
121	10-22-65
121	1-20-69

OUA KITS

(SPRING & COLLET)

	DEL DATE
2 KITS	7-18-67
1 KIT	9-11-67
1 KIT	12-21-67
1 KIT	3-13-68

OUA KITS

(LIMIT STOPS)

	DEL DATE
1 KIT	6-21-68
1 KIT	6-27-68
1 KIT	6-28-68
1 KIT	7-22-68
1 KIT	7-26-68
1 KIT	9-4-68
1 KIT	9-12-68

EYEPIECE KITS

(VIBRATION PROOFING)

	DEL DATE
1 KIT	6-26-68
7 KITS	7-3-68
1 KIT	7-9-68
8 KITS	7-16-68
5 KITS	7-19-68
1 KIT	7-26-68
1 KIT	8-28-68
1 KIT	8-30-68
1 KIT	9-17-68
1 KIT	9-30-68
1 KIT	1-24-69
1 KIT	1-31-69
1 KIT	2-5-69
1 KIT	4-1-69

Table 2. Apollo LM & GSE (LM) Deliveries

AIRBORNE (AOT)

A. BREADBOARDS UNIT	DEL. DATE
THERMAL BB	8-10-65
MECHANICAL BB	8-27-65
MSC TRAINER	12-30-65
B. PREPRODUCTION	
WEIGHT & CG DUMMY	8-31-65
MECHANICAL GAUGE	6-15-65
TRAINER SIM	9-28-65
WEIGHT & CG DUMMY	10-28-65
TRAINER SIM	10-15-65
WEIGHT & CG DUMMY	10-28-65
LEARNER MOD	6-26-65
C. PRODUCTION	
601	2-9-66
602	6-10-66
603	7-19-66
604	9-20-66
605	10-7-66
606	11-4166
607	12-2166
608	12-22-66
609	1-31-67
610	3-6-67
611	5-7-67
612	8-31-67
613	12-8-67
614	1-5-68
615	1-31-68
616	4-1-68
617	5-29-68
618	7-25-68
619 (SPARE)	10-4-68
620	
622	CANCELLED
622	

AOT SUNSHADES

	Delivery Date
PP-1	2-9-68
PP-2	3-11-68
P-1	5-8-68
P-2	5-27-68
P-3	6-17-68
P-4	7-3-68
P-5	7-16-68
P-6	8-23-68
P-7	9-6-68
P-8	9-19-68
P-9	10-4-68
P-10	10-11-68
P-11	11-1-68
P-12	11-7-68
P-13	11-15-68
P-14	11-25-68
P-15	CANCELLED
P-16	
P-17	
P-18	

AOT RETROFIT KITS

(HARNESS SHIELD)

	DEL. DATE
4 KITS	7-3-68
9 KITS	7-24-68

GSE RETROFIT

	DEL. DATE
2 RETICLE DIMMER KITS	3-12-68

AOT GROUND SUPPORT EQUIPMENT

UNIT	DEL DATE
OPTICS CLEANER KIT	11-3-65
AOT TESTER 1	5-20-66
AOT TESTER 2	11-18-66
AOT SHIPPING CONT 1	12-30-65
2	2-9-66
3	6-10-66
4	11-4-66
5	12-2-66
6	1-19-67
7	1-19-67
AOT SHIPPING CONT 8	1-19-67
AOT LENS COVERS	CON-CURRENT WITH DEL OF EACH AOT
THEODOLITE	5-12-66
OPTICS CLEANER KIT	9-17-66
TRIPOD	3-2-66
TRIPOD	3-9-66
SUNSHADE ALIGNMENT FIXTURE FTE 1	5-26-68
SUNSHADE ALIGNMENT FIXTURE SN 1	7-17-68
SUNSHADE ALIGNMENT FIXTURE SN 2	7-17-68
GSE PROTECTIVE COVERS (12)	7-16-68
PROTECTIVE DUST COVERS (12)	9-30-69

HIGH DENSITY FILTERS

	DEL. DATE
2 UNITS	10-19-67
2 UNITS	11-15-67
1 UNIT	12-20-67
1 UNIT	12-27-67
1 UNIT	1-2-[illegible]
1 UNIT	1-15-68
2 UNITS	2-9-68
2 UNITS	4-18-68
2 UNITS	8-20-68
1 UNIT	9-18-68

LM RETROFITS

	Delivery Date
602	7-29-66
611	7-31-67
604	9-22-67
610	10-27-67
609	12-19-67
606	2-5-68
607	3-8-68
608	4-17-68
SIMULATOR NO. 1	5-1-68
SIMULATOR NO. 2	6-28-68

Table 3. Apollo GSE (CM) Deliveries

BLOCK I-100 & BLOCK II GROUND SUPPORT EQUIPMENT

UNIT	DEL DATE
PRECISION TEST FIXTURE	9-22-65
FUNCTIONAL TESTER	7-28-66
STAR & HORIZON SIMULATOR	8-6-65
STAR & HORIZON SIMULATOR	4-30-66
THEODOLITE & SUPPORT	3-2-66
THEODOLITE & SUPPORT	5-16-66
ALIGN CERT FIXT	1-28-66
ADJ. MIRROR & PED. ASSY.	6-16-66
VARIABLE DEVIATION WEDGE	9-14-65
VARIABLE DEVIATION WEDGE	9-14-65
VARIABLE DEVIATION WEDGE	9-13-65
PORTABLE LIGHT ASSY	7-30-65
	7-30-65
	7-30-65
PORTABLE LIGHT ASSY	7-30 65
ALIGNMENT MIRROR ASSY	2-9-66
SHAFT ACCURACY TESTER	10-22-65
AUTOCOLL PLATE ASSY 0°	9-28-65
0° (2)	9-28-65
0° (2)	9-29-65
0°	10-5-65
0°	12-30-65
0°	3-2-66
45° (2)	8-2-65
45°	8-2-65
AUTOCOLL PLATE ASSY 45	3-2-66
RETROREFLECTING PRISM	11-17-65
RETROREFLECTING PRISM	11-17-65
OPTICS CLEANER KIT	8-4-65
	8-21-65

UNIT	DEL DATE
OPTICS CLEANER KIT	10-8-65
	11-8-65
OPTICS CLEANER KIT (2)	11-19-65
STAR & HORIZON SIMULATOR C/F	8-6-65
	10-8-65
	11-18-65
	11-18-65
	12-15-65
STAR & HORIZON SIMULATOR C/F	12-17-65
SXT/SCT LENS COVER (31 SETS)	10-31-66
SYSTEM CONNECTORS COVERS (25 SETS)	7-28-66
G & N FIXTURE STAND	7-2-65
	8-31-65
	9-14-65
	9-23-65
	9-24-65
	11-8-65
	11-8-65
G & N FIXTURE STAND	12-10-65
OUA PROTECTIVE STORAGE CONTAINERS (10)	7-25-69

GSE MODIFICATION

PORT LIGHT MOD	6-1-66
PRECISION TEST FIXTURE (EP_1)	8-6-65
PRECISION TEST FIXTURE	10-7-65
FUNCTIONAL TESTER (EP_1)	7-31-65
FUNCTIONAL TESTER	7-29-66
PTF CALIBRATION KIT (EP_1)	7-2-65
PTF CALIBRATION KIT	8-20-65
PORTABLE LIGHT ASSY RETRO (4)	2-8-66
PORTABLE LIGHT ASSY	5-31-66
PORTABLE LIGHT ASSY KITS (9)	11-28-66

UNIT	DEL. DATE
STAR HORIZON CERTIFICATION	
2 KITS	4-25-66
3 KITS	7-12-66
1 KIT	9-9-66
FUNCTIONAL TESTER	
3 KITS	8-23-66
AZIMUTH REFERENCE	
1 KIT	12-6-65
G&N INST. QUAL. FIXTURE	
1 KIT	12-6-65
2 KITS	4-18-66
ALIGN. CERT. FIXTURE	
1 KIT	1-27-66
1 KIT	3-21-66
1 KIT	4-23-66
2 KITS	12-9-66
SHAFT ACCURACY TESTER	
3 KITS	6-23-66
VARIABLE DEVIATION WEDGE	
9 KITS	4-30-69

MDV

MDV SHIPPING CONT (3)	JUN-64
MDV SHIPPING CONT (5)	SEP-64
MDV TESTER (2)	MAY-64
RETRO REFLECTING PRISM C/E	APR-65
	MAY-65
	MAY-65
	MAY-65
OPTICS CLEANING KITS RETRO S/N 1 THRU 8	11-10-67

BLOCK I GROUND SUPPORT EQUIPMENT

UNIT	DEL DATE
PRECISION TEST FIXTURE	MAR-64
PRECISION TEST FIXTURE	MAY-64
FUNCTIONAL TESTER (2)	MAY-64
ALIGNMENT MIRROR ASSY	MAR-64
ALIGNMENT MIRROR ASSY (2)	APR-64
ALIGNMENT MIRROR ASSY (2)	MAY-64
AUTOCOLL PLATE ASSY 0°	FEB-64
0° (5)	MAR-64
0°	APR-64
0	MAY-64
0°	JUN-64
0° (2)	DEC-64
0° (2)	JAN-65
0°	FEB-65
45°	FEB-64
45° (2)	MAR-64
45°	APR-64
AUTOCOLL PLATE ASSY 45°(4)	MAY-64
VARIABLE DEVIATION WEDGE	FEB-64
VARIABLE DEVIATION WEDGE (5)	MAR-64
ADJUSTABLE MIRROR (2)	FEB-64
ADJUSTABLE MIRROR (4)	APR-64
THEODOLITE & STAND	FEB-64
THEODOLITE & STAND (5)	MAR-64
THEODOLITE & TOOL BAR	MAR-64
SHAFT ACCURACY TESTER	OCT-64
G & N INST QUALITY FIXT	FEB-65
G & N INST QUALITY FIXT (2)	FEB-65
AZIMUTH REFERENCE FIXT	FEB-65
	FEB-65
	FEB-65
	JUL-65
AZIMUTH REFERENCE FIXT	JUL-65

UNIT	DEL DATE
RETRO REFLECTING PRISM	FEB-65
	JUN-65
	JULY-65
	JULY-65
RETRO REFLECTING PRISM	OCT-65
PORTABLE LIGHT ASSY (5)	JUL-64
G & N CERT FIXT	FEB-65
G & N CERT FIXT (2)	MAR-65
OSS SHIPPING CONT (4)	JUN-64
OPTIC NAV-BASE SHIPPING CONT	DEC-64
	JAN-65
	FEB-65
	MAR-65
	JUN-65
	SEP-65
	OCT-65
OPTIC NAV-BASE SHIPPING CONT	OCT-65

FUNCTIONAL BREAKDOWN OF ORGANIZATION

In the early months of the development of Apollo, the program was headed by a program manager whose upward channel of communication was through the executive staff but with direct responsibility to the chief executive. Subordinated to the program manager were the following functions: Project Administration, Reliability, Quality Assurance, Project Engineering, Scientist and Analysis Group and Documentation. All other services were supplied by the centralized parent organization.

During the latter part of 1962, Kollsman decentralized into divisions and the Apollo Program manager assumed directorship of the Apollo/LM Programs directly responsible to the General Manager, Space Division. The Apollo/LM Program was a semi-autonomous operation. This was effected, in advance of the prime hardware implementation phase, in order to better meet stringent Apollo requirements and generally enhance program effectiveness. Since the sole function of the Kollsman Apollo Program organization was the execution of this contract, it was intimately structured to be responsive to the dynamic needs of the program.

From inception and through the full period of performance, the Kollsman Apollo Team was comprised primarily of Senior personnel who had long tenure with the company.

In light of President Kennedy's stated policy for an accelerated space program and with considerable knowledge as to NASA's objectives, the Apollo Program Office at Kollsman had a sound understanding of the flavor of the program it had to develop and direct. Much emphasis was placed on the careful selection of personnel. Aside from the obvious, technical competence requirements, much stress was placed on personal qualifications. Qualities of integrity, innovativeness, high level and sustained motivation capabilities, flexibility, etc., were of foremost importance. As the program developed and individuals were assigned managerial authority in each of the major functional areas, it was anticipated that they would have to serve two agencies. The one, of course was the in-house authority. The other was the MIT/IL authority, who by vested design cognizance authority from NASA made the final technical decisions in all matters related to hardware and software. For each operating discipline at MIT, there was a corresponding engineering manager at Kollsman.

In addition to performing as operating managers, these people were assigned the responsibility of serving as the principal advisors to the program manager. This departure from traditional organizational concepts was done to:

a. keep the program manager and each group abreast of rapid developments in all functional areas of the program. It provided instant communications between groups (especially important because of the extensive interface required).

b. bring specialization into executive decision making thereby promoting consistent, sound judgement.

c. establish rapid and concise responsibility for action items.

d. reduce organizational complexity which would have been especially detrimental to this type of program.

e. reduce administrative expense.

As the program progressed, additional functions were brought under program control for purposes of accurate and rapid response. By major categories, these included: Manufacturing Operations, Configuration Management, Administrative Services and Field Operations, see Figure 1. Special Apollo Operating Procedures (AOP's) were prepared to define all aspects of the program organization as well as the relationships between the program, Kollsman corporate services and outside agencies. Special controls were instituted to prevent even the most insignificant changes from being made without program review and approval. As an example, the Kollsman Engineering Standards department prepared and maintained numerous material and process specifications under program guidance. Special numbers were assigned for standards use but with full control retained by program. The Kollsman Machining Standards which are used by subcontractors as well as Kollsman shops was refined and assigned a unique document number for program control.

Perhaps the single, most distinguishing feature between the Apollo Program and all other programs was its documentation; both in quantity and comprehensiveness. It transcended all phases of the G&N program including: Mission objectives and goals, Research and Analyses, Engineering Design, Production, Test and Evaluation and Training and Use.

The comprehensive documentation was a major factor in providing clear, precise communication and excellent controls to all participants in the program from the initial design studies to the delivery of the last flight units.

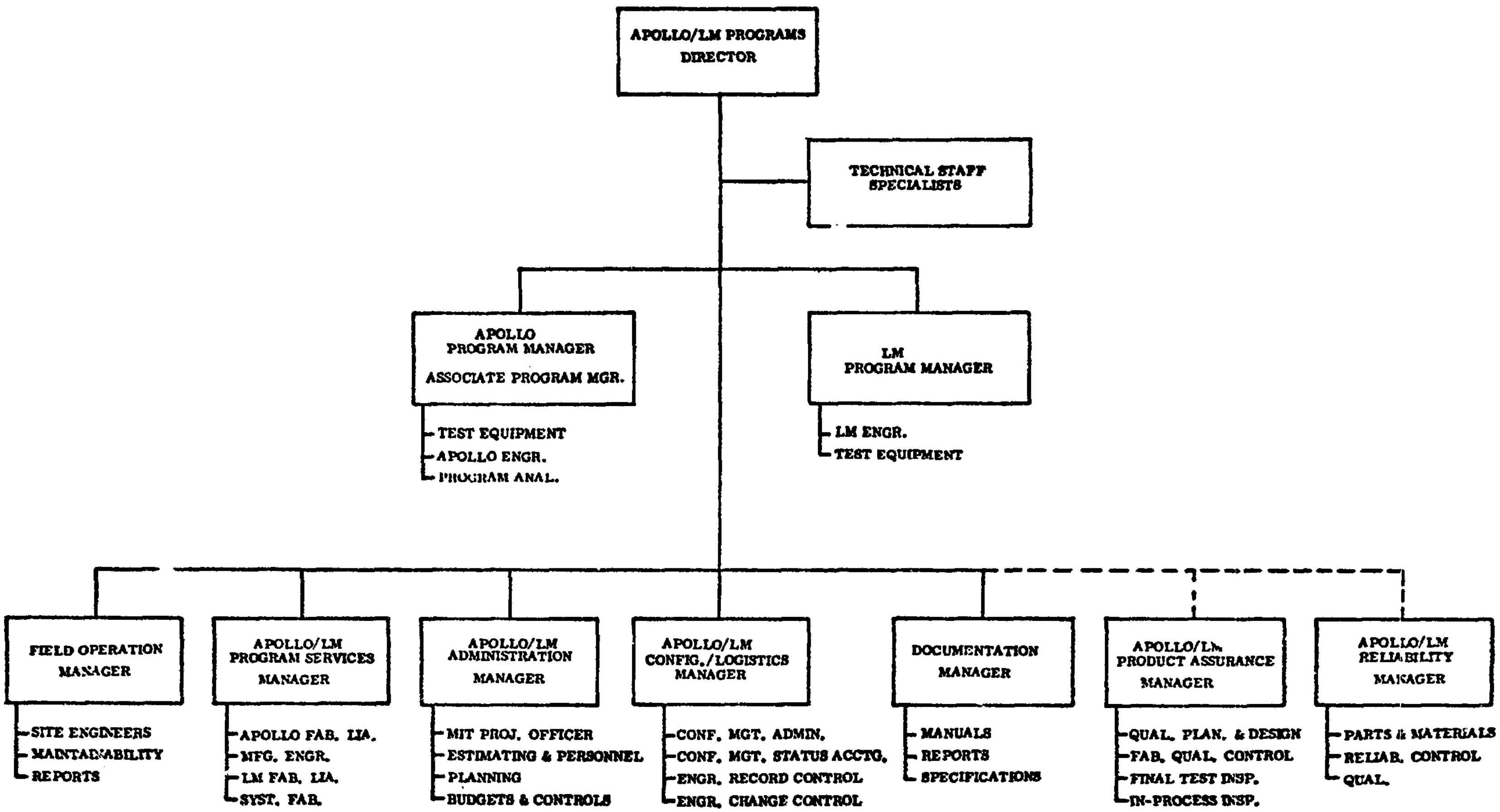

Figure 1. Apollo/LM Program Organization

KOLLSMAN INSTRUMENT CORPORATION

SIGNIFICANT MILESTONES AND ACCOMPLISHMENTS

Man has been to the moon and back. The Apollo missions have been near letter perfect. Each individual who has contributed directly or indirectly to the Apollo program is proud of the men and machines, a small part of which was his own special "labor of love". As American citizens there is special pride in this magnificent achievement. A truly "giant leap" rendered by a peaceful nation in service to the brotherhood of man.

Shortly after the safe return of the first Lunar Landing Team, it was stated that now that man has landed on the moon and returned, we can solve all of the problems of our society and environment. Indeed, the success of the Apollo Program has proven that the problems of our society are not insurmountable, and that by applying the united efforts of all of our people and resources we can accomplish these goals. History may well regard the confidence in our ability to accomplish the near-impossible as the Apollo Program's most important contribution.

Perhaps the one most overriding feature throughout the program which has enabled everyone to do a proper job has been the clarity with which NASA objectives, and ground rules for meeting those objectives, have been received at Kollsman. As modifications and redirections evolved the communications link between NASA, AC Electronics and Kollsman operated flawlessly. In addition the support and guidance provided by AC Electronics has enabled Kollsman to maintain a state of excellent management, engineering, manufacturing and financial health permitting complete responsiveness to the needs of the program.

A brief summary of the major milestones of Kollsman's participation in the Apollo program is as follows:

High caliber personnel were supplied to the MIL/IL resident effort for the design and development of the G&N equipment. The effort covered the period from July 1962 through June 1966 and peaked at 26 people.

The initial drawing releases of OUA Block I drawings started in Feb. 1963 and continued for a period in excess of six months. Kollsman commenced purchase of long lead items in March 1963. It is noteworthy that this short turn-around was made possible by the comprehensive design review which was performed by Kollsman prior to drawing releases. Among other things, the review resulted in improved drawing integrity and early decisions on "make or buy".

KOLLSMAN INSTRUMENT CORPORATION

Early in 1963, Kollsman submitted SCD drawings (prepared by its Standards Department) to MIT/IL for approval. The nature, depth and quality of the information shown on these drawings was instrumental in upgrading the standards of all SCD's for the G&N program and the eventual decision to have each G&N subcontractor prepare his own SCD's.

The first OUA to be delivered under Class A regulations was AGE 3 in February 1964. This was an Optical Evaluation Unit for MIT/IL use.

The second unit (OUA AGE 1) was delivered in March 1964. This was the Thermal Test and Analyses unit and test results appear in report No. AA-65-219, dated 5/15/65.

The third unit (OUA AGE 2) was delivered in April 1964. Mechanical Integrity tests were performed on this unit between 5/15/64 and 4/15/65. Results appear in report No. AA-65-223, dated 6/15/65.

Block II drawing releases began at MIT/IL (Fall 1964). Kollsman precluded a rash of new problems by embarking on a thorough review of all outstanding Block I changes and problems and transmitting detail comments and recommendations to MIT/IL for incorporation into Block II drawings prior to release. This was done expeditiously and effectively with no delay imposed on release schedules. Results of this effort are immeasureable in terms of time and cost savings.

During the early phases of Block II production, Kollsman pursued vigorous development of alternate sources of supply to optimize quality and cost and to preclude production stoppages. Similar effort had been expended for the Block I manufacturing.

The first Block II unit (redesignated Block I-100) was delivered in May 1965. This unit was used as a Learner's Model. Kollsman made extensive and innovative use of this unit (and later the AOT Learner's Model) for the solution of numerous problems that would otherwise require exhaustive, expensive and time consuming tests.

June 1965 saw the quantity of Kollsman personnel working on the Apollo program reached a peak of 570 equivalent people.

Throughout the development and manufacturing of apollo hardware, many design problems were encountered. Kollsman's expertise in engineering and manufacturing and its closeness to the problems enabled it to recommend fast and sound solutions to MIT/IL for approval. An emergency (pipeline) procedure was established between Kollsman and MIT/IL for mutual agreement on all urgent matters.

The emergency procedures included AC Electronics during its tenure as prime contractor. Implementation of the above eliminated numerous potential schedule delays and avoided unnecessary scrappage of parts. The soundness of all judgments exercised is exemplified by the fact that no agreement was ever overturned or resulted in hardware malfunction or rework.

During the performance of the program, the state-of-the-art was challenged and overcome many times. Volume II of this report adequately demonstrates this activity. However, we wish to note three instances here, that depict the depth of detail investigations which represent the typical quality performance exhibited by members of the Apollo team throughout the program. These are: Loctite Evaluation Test Report No. AE-66-010, Preforming of Self-locking Screws, Report No. AE-67-032 and Interferometric Measurement of Flatness and Coplanarity of SXT Mirror Mounting Surfaces, Report No. AE-66-013. The first two studies involve materials and procedures which had wide use on the G&N system. The studies resulted in an understanding of the materials, their application and use well beyond anything previously known. It raised the status from general commercial use to stringent, well defined aerospace requirements. The third study developed new interpretations and measurement criteria for interference fringe patterns between optical flats in simultaneous contact with three mounting pads. A special NASA citation was awarded the engineer who authored this study.

The Qualification Test for the OUA was performed on OUA AGE 201A during the period 2/5/66 through 9/15/66.

The following is an Honor Roll of Kollsman equipment which performed successfully on Apollo Missions:

Apollo Flight	OUA S/N	AOT S/N
202	12	NA
4	7	NA
5	NA	9
6	009	NA
7	024	NA
8	019	NA
9	027	18
10	022	16
11	020	15
12	026	19

KOLLSMAN INSTRUMENT CORPORATION

Kollsman's performance on Apollo was highlighted by the following achievements:

- Fulfilled all commitments of the program and underran target costs by more than $1 million.
- Consistently delivered "waiver free" flight hardware.
- Delivered most hardware on or ahead of schedules.
- Delivered state of the art hardware which performed successfully on all manned flights.
- This hardware performed all of its originally intended functions and, with use, found new applications. Kollsman's pride in this equipment was gratified when Apollo 10 astronaut Tom Stafford described it as "the best gear on board".
- Performed to the letter and intent of stringent Apollo program documentation requirements. As testimony, Kollsman was proud to accept AC Electronics' presentation of the Pride in Performance Certificate for excellence in Configuration Management.
- Reduced customer cost for spares primarily due to realistic, timely and well documented spares provisioning. Of particular note was the additional reduction which resulted from a comprehensive analysis made by Kollsman of all obsolete Block I spares as to the feasibility of converting them to valid Block II spares. This analysis culminated in the decision to convert approximately 700 Block I spare parts into "flight worthy" Block II spares. The salvage of these parts resulted in a cost saving of over $400,000.
- Conducted an aggressive quality assurance corrective action system and extensive vendor support which resulted in reduced nonconformances. This was a significant factor contributing to timely delivery, maximum utilization at G&N level, low spares requirements, cost savings and reduced support personnel.
- Provided a well trained professional staff of field support personnel. Kollsman field engineers displayed initiative, outstanding capability and the willingness to tackle any assignment at any hour of the day or night. These men on frequent occasions, received praise from AC Electronics, MIT, and NASA including, NASA's special Snoopy award for outstanding achievement.

- Responded to urgent NASA request to design, develop, qualification test, and fabricate Class A hardware for the Apollo Rangefinder. This device was used for rendezvous of the Apollo 9 Command Module and LM. Total elapsed time from the concept through delivery of first flight unit was just over two months. Qualification test was completed less than three months after start date. The flight unit operated satisfactorily on the Apollo 9 mission in March 1969.

- Responded to unique field problems by the immediate dispatch of appropriate specialists to sites and the maintenance of support teams at Kollsman.

- The Apollo assembly and test facility (white room) was built at Kollsman's expense to provide the finest available environmentally controlled area for Apollo. Other Kollsman funded facilities such as the Dual Thermal Vacuum Chamber, Solar Simulator, Vibration Exciter and Precision Beryllium Machine Shop were made available on a top priority basis.

- The AOT Sunshade project was a significant challenge. Where most vendors refused to quote this most difficult assembly, Kollsman's model shop successfully fabricated a qualification test model and numerous production units within stringent delivery schedules. The stringent specifications for the Sunshade significantly add to Kollsmans design and development accomplishments.

- Kollsman management continually demonstrated initiative in "moving out" in advance of authorization where sound judgment indicated program needs justified extraordinary action.

- All CAT (Configuration and Traceability) tapes matched 100% correct against AC Electronics tape deck over the last three years of the program. This is especially significant since Kollsman's tape includes revision letters and serialization/lot control for all parts and assemblies.

- The longevity of individual personnel was an important factor in the success of the program. The majority of people working on the program in 1969 were assigned to the program during its early stages.

KOLLSMAN INSTRUMENT CORPORATION

Kollsman's management was encouraged to use its resources and know how throughout the program. Its job was to handle technology responsibly and focus it imaginitively toward Apollo objectives. A climate was established in the corporate culture which put its trust in people and encouraged imaginative actions. In retrospect it is our judgment that Kollsman's performance was made possible by the following prime factors: clear, comprehensive and common objectives, established priorities, excellent customer support, rigid communications, good public relations, effective organization and sound management.

The total Kollsman community is ennobled and enriched by its participation in the Apollo program. The experience has reshaped our mold to better meet the rising needs of the community.